

Influence of an Apical Negative Pressure Irrigation System on Bacterial Elimination during Endodontic Therapy: A Prospective Randomized Clinical Study

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Abstract

Introduction: Recent *in vitro* studies that use an apical negative pressure irrigation system, EndoVac, have demonstrated promising results in the production of debris-free root canals, while also preventing potential extrusion of irrigants into the periapical region. We conducted a randomized, controlled, prospective clinical study to determine whether the use of EndoVac irrigation (EndoVac group) was more efficient compared with standard needle irrigation (control group) in obtaining canals from which microbes could not be cultivated.

Methods: Routine endodontic therapy was performed in 48 patients with necrotic, single-rooted, single-canal teeth. The patients were randomly assigned to either the EndoVac group ($n = 25$) or control group ($n = 23$). Irrigation with either method was carried out with 0.5% sodium hypochlorite. After surface disinfection, before instrumentation and on completion of chemomechanical preparation, intracanal microbial samples were obtained and cultured under anaerobic conditions. The frequency of microbial cultivability by using either irrigation system was analyzed. **Results:** The frequency of obtaining culture-negative root canals was 90.9% and 82.6% for the control group and EndoVac group, respectively. There was no significant difference in the antimicrobial efficacy of either control group or EndoVac group (Fisher exact test, $P = .665$). Furthermore, no significant association between study variables and the irrigation systems' antimicrobial efficacy was found ($P > .05$).

Conclusions: The results of this prospective *in vivo* study demonstrate that the antimicrobial efficacy of EndoVac irrigation is comparable to that of standard irrigation. (*J Endod* 2012;38:1177–1181)

Key Words

Apical negative pressure, endodontic therapy, EndoVac, irrigation, microbial culture

Apical periodontitis is most commonly caused by an infected root canal system subsequent to pulp necrosis. It represents an attempt by the host's immune system to achieve equilibrium between itself and bacterial/necrotic debris (1). Several animal and human studies have established the etiologic role played by bacteria and their by-products in causing apical periodontitis (2–6). Therefore, the primary goal of endodontic therapy is to attempt to disinfect the root canal, thus providing an environment for apical healing. This is substantiated by studies over the decades that demonstrated higher rates of therapeutic success when teeth were obturated after negative root canal microbial cultures (7). To this end, canal disinfection is generally accomplished by chemomechanical root canal preparation, in which irrigation plays a critical role.

Several irrigants that are used in routine endodontic practice possess the antimicrobial properties required for root canal disinfection. Sodium hypochlorite (NaOCl) used at concentrations ranging from 0.5%–6% (8–10) is the most commonly used endodontic irrigant. In addition to possessing wide-spectrum antimicrobial properties, it has the ability to dissolve organic material such as pulp tissue and collagen (11). In addition, in conjunction with ethylenediaminetetraacetic acid (EDTA) for smear layer removal, it can access microbes in dentinal tubules and lateral accessory canals (12). Irrigant delivered into the canal by using a side-vented or notched needle allows for removal of debris through a flushing action and direct contact of the irrigant with the apical microflora (13, 14).

The antimicrobial and flushing action of traditional needle irrigation is dependent on the depth of needle placement and concentration and volume of irrigant used. Also, increase in apical preparation size aids in more volume of irrigant delivery (15). Fluid dynamics and improper needle placement can lead to “vapor locks” and inadequate antimicrobial action (16, 17). Furthermore, the positive pressure generated at the end of the needle has the potential to force irrigant solution and microbial debris into the periapical area, thereby compromising the goal of endodontic therapy (18–20). This is especially the case when irrigating with a cytotoxic irrigant such as NaOCl. Concern for such extrusion led to the development of an apical negative pressure irrigation system.

EndoVac (SybronEndo, Orange, CA), an apical negative pressure irrigation system, was developed as a means to irrigate and remove debris at the apex without forcing irrigation solution into the periapical area. In this system, irrigant is delivered into the pulp chamber through a master delivery tip. A primary attachment connected to a high-volume suction unit prevents irrigant overflow. The adapter assembly has a second attachment with either a macrocannula/microcannula at the other end. The

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cannulas are used in sequence to irrigate the canal to full working length. An apical current flow is generated, because of apical negative pressure, when the cannula tips are placed at various depths within the root canal.

Several recent studies have shown that EndoVac is more efficient in apical debridement when compared with standard irrigation (21–24). It has been shown to improve the antimicrobial efficacy of irrigants (25, 26). In addition, it has been observed that EndoVac irrigation can result in a significant reduction of postoperative pain in patients (27). Despite the plethora of studies comparing the efficacy of EndoVac with standard irrigation, there have been no randomized, *in vivo* clinical studies that have demonstrated differences in antimicrobial efficacy. The purpose of this study was to investigate the antimicrobial efficacy of 2 irrigation methods, EndoVac and standard irrigation, in obtaining negative cultures from infected root canal systems.

Materials and Methods

This was a prospective, randomized clinical study conducted in patients who presented for routine endodontic therapy during 2 clinical visits at the Endodontology Clinic at the University of Connecticut Health Center. The study was approved by the Institutional Review Board at the University of Connecticut Health Center.

Patient Selection

A total of 52 patients requiring routine endodontic therapy of single-rooted teeth were recruited to this study. Four patients with clinically normal pulp that needed endodontic therapy for restorative reasons were randomly assigned to serve as negative controls. The inclusion criteria for the remaining 48 patients included only those single-canal teeth diagnosed with pulp necrosis and symptomatic/asymptomatic apical periodontitis as tested with routine diagnostics. The patients were randomly assigned to 1 of the irrigation groups by using a Web-based program (www.randomizer.com). The treatment protocol was explained to all qualifying patients, and informed consent was obtained. Endodontic therapy throughout the study was performed by 2 separate operators (R.P., A.A.).

Treatment Protocol

Teeth were isolated and disinfected with 30% hydrogen peroxide (Sultan Healthcare, Hackensack, NJ), followed by 5% iodine tincture (Lugol's solution; Gallipot Inc, St Paul, MN) (28). After complete removal of restoration and caries, tooth surface disinfection was repeated. The disinfectant was inactivated with 5% sodium thiosulfate (American Reagent Labs Inc, Shirley, NY). The tooth surface was rinsed with sterile saline. At this time the first microbial sample (S1) was obtained. All microbial samples were obtained by using 3 paper points. The access cavity was prepared, and the canal was located. If multiple root canals were identified at this time, the patient was excluded from the study; conventional root canal therapy was completed regardless of eligibility. A #10 hand file was inserted into the canal 1 mm short of the estimated working length as ascertained from the preoperative radiograph. The canal was filled with sterile saline, and a second microbial sample (S2) was obtained. Chemomechanical preparation involved preflaring the canal, obtaining a working length with the aid of an apex locator and/or a radiograph. Instrumentation was conducted by using K & H hand files (Brasseler USA, Savannah, GA) and ProTaper nickel-titanium file rotary system (DENTSPLY, Tulsa Dental, Tulsa, OK) by using crown-down method. The canal was enlarged to a minimum size of #35 master apical file (MAF). Irrigation in the 2 study groups (control group and EndoVac group) was carried out by using 40 mL of buffered 0.5% NaOCl solution (pH ~9.0, Dakin solution; Century

Pharmaceuticals Inc, Indianapolis, IN). After complete chemomechanical preparation, the canal was rinsed with 5% sodium thiosulfate and filled with sterile saline. A third microbial sample (S3) was obtained at this time. The canal was flushed again with 0.5% NaOCl, dried with paper points, and filled with a slurry of calcium hydroxide (Henry Schein, Melville, NY) with the aid of a lentulo spiral. The tooth was then temporized with a 3- to 4-mm layer of Cavit (3M ESPE, St Paul, MN), followed by GC Fuji IX (GC Company, Tokyo, Japan) restoration. Standard postoperative instructions were given to each patient. The patient was then scheduled for a second clinical visit after a minimum period of 1 week.

Irrigation Protocols

Standard irrigation (control group) was carried out by using a plastic syringe and 27-gauge side-vented monoject stainless steel needle (Kendall, Mansfield, MA). The needle was placed into the canal without binding and within 3 mm of the working length throughout the process. On completion of instrumentation, the canal was flushed with 17% EDTA for 30 seconds and rinsed again with 0.5% NaOCl solution.

For the EndoVac group, the master delivery tip of the EndoVac device was placed at the access opening to constantly deliver 0.5% NaOCl solution, filling up the root canal system. On completion of instrumentation to the size of MAF, the macrocannula tip was used to deliver irrigant up and down the canal for 1 minute. This was followed by 3 cycles of microcannular irrigation. Each cycle of microcannular irrigation consisted of the tip being placed at full working length for 6 seconds and then withdrawn 2 mm from full working length for 6 seconds. This was repeated for 5 times during a period of 30 seconds. Microcannular irrigation was carried out by using the irrigants in the following order: 0.5% NaOCl (cycle 1), 17% EDTA (cycle 2), and 0.5% NaOCl again (cycle 3).

Analysis of Microbial Culture

Microbial samples were obtained with 3 sterile paper points dropped into culture tubes containing 8 mL of BBL medium at each given time point. The tubes received numbers 1–52 and were designated with their respective sample numbers (S1–S3). All microbial samples were incubated in BBL thioglycolate anaerobic culture medium, enriched with vitamin K1 and hemin (BBL medium) (BD Biosciences, Sparks, MD). The culture tubes were incubated at 37°C for 1 week. The samples were evaluated for microbial growth periodically. Tubes of culture media that remained clear at the end of 1 week were recorded as being culture-negative. Samples that demonstrated turbidity were recorded as being culture-positive. For all positive cultures, the day on which the sample showed turbidity was recorded. Any teeth with culture-positive S1 samples were excluded from the study at this point. Teeth were included in the study only if S2 samples were culture-positive. The results from microbial sample S3 were analyzed for evaluating the antimicrobial efficacy of the irrigation methods.

Data Recording and Statistical Analysis

Individual, de-identified treatment cards were made for the 52 patients enrolled in the study. The treatment cards recorded the patient number, tooth number, presence of preoperative symptoms, operator, size (in millimeters) of the preoperative periapical radiolucency, MAF size (35 and above), and presence of flare-up. The results from microbial samples obtained were recorded on a password-protected worksheet.

Analysis of the results was carried out by using Fisher exact test with a level of significance of $\alpha = 0.05$. Multivariate logistical regression

was used to evaluate the effect of study variables: preoperative symptoms, operator, lesion size, MAF size, and the presence of flare-up.

Results

Antimicrobial Efficacy of Standard Irrigation and EndoVac

Three teeth were excluded from the study, 2 because of coronal surface microbial contamination (positive S1 samples) and 1 after discovery of multiple root canals (Tables 1 and 2). The remaining 45 teeth were S2 culture-positive and met all of the inclusion criteria (Tables 1 and 2). It was determined that sample S3 was most representative of the ability of either irrigation system in obtaining microbe-free root canals. Of the 45 samples from either irrigation group a total of 6 (14%) demonstrated microbial growth, as evidenced by turbid culture media; 39 (86%) were negative for microbial growth. Four of 23 samples from the EndoVac group (17.4%) were positive for microbial growth, whereas only 2 of 22 from the control group (9.1%) exhibited growth (Table 3). Standard irrigation protocol was more effective in obtaining canals from which microbes could not be cultivated; however, this difference was not statistically significant (Fisher exact test, $P = .665$).

Influence of Study Variables on Antimicrobial Efficacy

Controlled Variables. After controlling for preoperative symptoms, operator, lesion size, MAF size, and the presence of flare-up, multivariate logistic regression was used to analyze any association between the irrigation protocol and ability to obtain a negative S3 culture. With the null hypothesis of no significant difference between EndoVac irrigation and standard irrigation and by using a likelihood ratio test, a P value of .515 was obtained. The null hypothesis was not rejected. Therefore, it was concluded that with all variables controlled for, there was no significant difference in the antimicrobial efficacy of EndoVac group and control group.

Independent Role of Variables. Because of the considerable variations noted in the values of the 5 variables (Tables 1 and 2), we independently analyzed (Fisher exact test) their potential effect on the observed antimicrobial efficacy of both irrigation methods. Independent analysis of each of the following variables did not reveal any statistically significant association between them and the ability of the irrigation systems in obtaining negative S3 samples: preoperative symptoms ($P = .179$), lesion size ($P = 1.000$), MAF size ($P = .460$), flare-up ($P = 1.000$), and operator ($P = .179$).

Discussion

The results from this study showed that EndoVac irrigation did not provide any added advantage over standard irrigation in obtaining canals from which microbes could not be cultivated. In addition, there was no statistically significant association between the 5 study variables and the efficacy of the 2 irrigation systems. These observations were in contrast to previous *in vitro* studies that demonstrated that apical negative pressure irrigation was more effective in (1) removing the smear layer (29), (2) preventing extrusion of NaOCl beyond apical foramina (30–32), (3) producing cleaner, debris-free canals (21–24), and (4) potentially improving the antimicrobial efficacy of irrigants (26). In addition, the 1 clinical study to date reported EndoVac to be effective in reducing postoperative pain (27). Although the results of this study differ somewhat from the aforementioned ones, it provides valuable information about the efficacy of these 2 chemomechanical aids. Furthermore, the *in vivo* design of this study allows for further evaluation of these initial results, as they pertain to periapical healing and therapeutic success, during the long-term with clinical and radiographic follow-up.

The results from several studies (33–35) over the decades underscore the importance of obtaining debris-free and microbe-free root canals and their correlation with endodontic success. Two recent studies in particular, an *in vitro* study by Hockett et al (26) and a dog

TABLE 1. Chemomechanical Preparation of Single-rooted Teeth by Using Standard Needle Irrigation

No.	Tooth No.	Lesion size (mm)	Preoperative symptoms	Microbial cultures			MAF	Flare-up	Operator
				S1	S2	S3			
1	24	4	N	+	+	—	50/.06	N	2
2	10	4	Y	—	+	—	50/.04	N	1
3	10	5	N	—	+	—	40/.04	N	1
4	10	3	N	—	+	—	55/.04	N	1
5	11	0	N	—	+	—	50/.04	N	1
6	9	5.5	Y	—	+	—	60/.04	N	2
7	8	2	N	—	+	—	80/.02	N	2
8	9	3	N	—	+	—	60/.02	N	1
9	7	4	N	—	+	—	40/.04	N	1
10	24	0.5	N	—	+	—	40/.04	N	2
11	7	4.5	Y	—	+	—	40/.04	N	2
12	21	5	N	—	+	—	45/.04	N	1
13	25	4	N	—	+	—	35/.04	N	1
14	11	4	N	—	+	—	35/.04	N	1
15	9	2	N	—	+	—	50/.04	Y	1
16	9	5	N	—	+	—	60/.02	N	1
17	24	6.5	N	—	+	—	35/.06	N	1
18	8	3	N	—	+	—	60/.02	N	1
19	7	4	Y	—	+	+	50/.04	N	1
20	29	1	N	—	+	—	40/.04	N	1
21	10	6.5	N	—	+	—	50/.04	N	2
22	28	1	N	—	+	+	45/.04	N	2
23	7	1	Y	—	+	—	40/.04	N	1
Control 1	13	0	N	—	—	—	40/.06	N	2
Control 2	20	0	N	—	—	—	40/.04	N	1

TABLE 2. Chemomechanical Preparation of Single-rooted Teeth by Using EndoVac Irrigation

No.	Tooth No.	Lesion size (mm)	Preoperative symptoms	Microbial cultures			MAF	Flare-up	Operator
				S1	S2	S3			
1	21	9	N	—	+	—	40/.04	N	2
2	8	2	Y	—	+	—	50/.04	N	2
3	11	3	N	—	+	—	40/.06	Y	1
4	25	5.5	N	—	+	—	40/.06	Y	2
5	8	6	Y	—	+	+	60/.04	N	2
6	24		Tooth was excluded from study because of multiple root canals						
7	20	6	N	+	+	—	50/.04	N	2
8	8	0.5	Y	—	+	—	55/.02	N	1
9	23	5	N	—	+	+	50/.04	N	2
10	27	4	N	—	+	—	45/.04	N	1
11	21	4	Y	—	+	+	40/.04	N	2
12	25	5	N	—	+	—	40/.04	N	1
13	26	4	N	—	+	—	40/.04	N	1
14	8	7	N	—	+	—	100/.02	N	1
15	29	2	N	—	+	—	50/.06	N	1
16	11	0.5	N	—	+	—	60/.02	N	1
17	12	1.5	Y	—	+	—	35/.04	N	1
18	20	1	Y	—	+	—	40/.06	N	2
19	9	4	Y	—	+	—	60/.06	N	2
20	20	5	Y	—	+	—	40/.06	N	2
21	8	1.5	Y	—	+	+	70/.06	N	1
22	25	1	N	—	+	—	40/.04	N	1
23	9	5	Y	—	+	—	70/.04	N	2
24	29	1	N	—	+	—	35/.04	N	1
25	7	10	N	—	+	—	50/.04	N	2
Control 1	7	0	N	—	—	—	40/.04	N	1
Control 2	20	0			—	—		N	

study by Cohenca et al (25), compared the antimicrobial efficacy of EndoVac and standard irrigation. The study by Hockett et al observed that EndoVac irrigation was effective in obtaining microbe-free root canals, 24 of 24 canals (100%) in the EndoVac group compared with 16 of 24 (67%) in the control group. They reported a significant improvement in bacterial elimination ($P = .004$). In comparison, the study by Hockett et al was conducted in extracted teeth by using a monoculture of *Enterococcus faecalis*, whereas the present study was an *in vivo* sampling from an established polymicrobial infection. The study by Cohenca et al, which was conducted in dogs, observed that EndoVac irrigation resulted in improved disinfection (88.6% negative cultures) in immature teeth with apical periodontitis, when compared with teeth treated with triantibiotic paste. However, they did not observe any statistically significant difference. In comparison, they did not compare EndoVac irrigation with standard irrigation with NaOCl (without antibiotic paste).

The microbial samples obtained for the purpose of this study followed the guidelines set out by Möller (28). All teeth were treated in a sterile operating field including appropriate disinfection of tooth surfaces (30% hydrogen peroxide and 5% tincture of iodine). Teeth with positive surface cultures (sample S1) were excluded from the study. Operators were calibrated, and microscopically identified

single-canal teeth were included in an effort to minimize potential variability in culture results. It was under these conditions that the current study observed no significant differences in the ability of either EndoVac or standard irrigation in obtaining sterile canals. In evaluating the canal sterility, the value of routine intracanal sampling as a true measure of sterility of the root canal system has been the subject of much debate. Whereas studies by Sjögren et al (7) showed increased success rate with culture-negative canals (94%) compared with culture-positive canals (68%), there are others who debate the notion that “culture-negative” is synonymous with canal sterility (7, 36). This is especially relevant because of the intricate root canal anatomy with numerous inaccessible areas with bacterial colonization. Because of these complexities, it is acknowledged that no sweeping conclusions regarding “true” canal sterility can be made. In addition, the current study used only 1 method for evaluation of microbial presence, a growth/no growth test during a period of 7 days. Nonetheless, the results in this study are valid, given the controlled conditions under which the 2 irrigation methods were evaluated.

Dakin solution (0.5% NaOCl) was used throughout this study because it is used for routine endodontic therapy at our institution on the basis of studies (37, 38). The original EndoVac protocol recommends using a concentration of 5.25% NaOCl. Almost all studies

TABLE 3. Comparing the Frequency of Microbial Cultivability with 2 Irrigation Systems

Irrigation method		Microbial sample S3		Total
		Culture-positive	Culture-negative	
Standard needle irrigation	n	2	20	22
	%	9.1	90.9	100.0
EndoVac irrigation	n	4	19	23
	%	17.4	82.6	100.0
Total patients	n	6	39	45
	%	13.4	86.6	100.0

investigating the efficacy of EndoVac have used NaOCl at concentrations ranging from 2.5%–6%. The use of 0.5% NaOCl in this study could be considered responsible for the lack of significant differences in antimicrobial efficacy between EndoVac irrigation and standard irrigation. Nevertheless, the control group had only 2 culture-positive canals out of 22 sampled when using 0.5% solution. It would be interesting to see whether using higher concentrations of NaOCl results in higher frequency of culture-negative canals by using the EndoVac system.

This is the first reported clinical study evaluating specifically the antimicrobial efficacy of an apical negative pressure irrigation system when used in routine endodontic treatment. This study showed no statistically significant difference in the antimicrobial efficacy of either EndoVac or standard irrigation. Importantly, these results do not directly address the overarching question of long-term healing after root canal treatment. The results from the long-term clinical and radiographic follow-up of the patients in this study will likely provide more insight into efficacy of this chemomechanical aid. Despite the lack of significant differences, this study provides valuable preliminary data and a framework for future *in vivo* clinical studies that use an apical negative pressure system.

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The authors deny any conflicts of interest related to this study.

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